ACRITARCHS OF THE MIDDLE SILURIAN ROCHESTER FORMATION OF SOUTHERN ONTARIO

by BINDRA THUSU

ABSTRACT. The Rochester Formation yields an acritarch microflora containing 24 genera and 46 species and varieties. Genus *Hemideunffia*; Species *Domasia canadensis*, *D. rochesterensis*, *Hemideunffia trifurcata*, *Elektoriskos simplex*, *Filisphaeridium bifurcatum*, *Gorgonisphaeridium wenlockium*, *Lophosphaeridium rugosum* and *L. microgranulosum*; varieties: *Deunffia furcata* var. *niagarensis*, *D. monospinosa* var. *tonowandensis*, and *D. ramusculosa* var. *rochesterensis* are proposed as new.

The Rochester netromorph assemblage, in particular the *Deunffia* and *Domasia* complex, shows a close resemblance to those from the Ilion Shale in Utica, New York, the Rochester Formation in West Virginia, and the Buildwas Beds in Shropshire, Britain. The stratigraphically restricted genus *Deunffia*, in particular *D. ramusculosa* and *D. furcata* which probably made their first appearance during the Lower Wenlockian times, is present in all four areas.

However, the absence of *Deunffia* and the presence of *Domasia* complex in the Wenlockian assemblages from Visby and Belgium suggest some connections with the Rochester assemblage; but the absence of *Deunffia–Domasia* complex in the Wenlockian assemblages from Spain and Sahara suggests fewer connections with the Rochester assemblage.

THIS paper contains results of acritarch studies on the Rochester Formation in southern Ontario (text-fig. 1). This region lies south-east of the Canadian shield and forms the marginal areas of the Michigan Basin and the Allegheny Trough.

The Rochester Formation is Tonawandian (Middle Silurian) in age and consists of calcareous shale with interbeds of argillaceous micrite or biomicrite. It is exposed at numerous localities along the Niagara Escarpment in New York and southern Ontario. It has a maximum thickness of 150 feet east of Walcott, New York. To the east the formation grades into the Herkimer Sandstone. To the west it thins successively to 60 feet near Niagara Gorge, 56 to 35 feet in the St. Catherines and Grimsby region, 14 feet at Hamilton, and 2·4 feet in the most northerly exposure at Clappison road cut, near Hamilton, Ontario (text-fig. 1). Well log data (Caley, 1940) indicate a general thinning of the formation from south-east to north-west Ontario without any lithological change.

South-easterly the Rochester Formation extends into Pennsylvania, Maryland, and West Virginia and varies from 20 to 40 feet in thickness, and maintains the same lithic character (Folk 1962).

Investigation by Thusu (1972) shows that the Rochester deposition in southern Ontario took place in a calm, subtidal, inner neritic, low-energy environment with good circulation, interrupted by occasional storms, which extended agitation into the subtidal zone.

However, conditions were not uniform within the Rochester sea and the several resulting environments undoubtedly influenced the distribution of fossils (Thusu 1972). For example, in southern Ontario and western New York bryozoans are present in large numbers, but to the east their number and diversity are greatly reduced. In Pennsylvania and West Virginia a normal marine fauna is absent. Folk (1962) postulates that parts of the Rochester Sea were protected by barrier-bars

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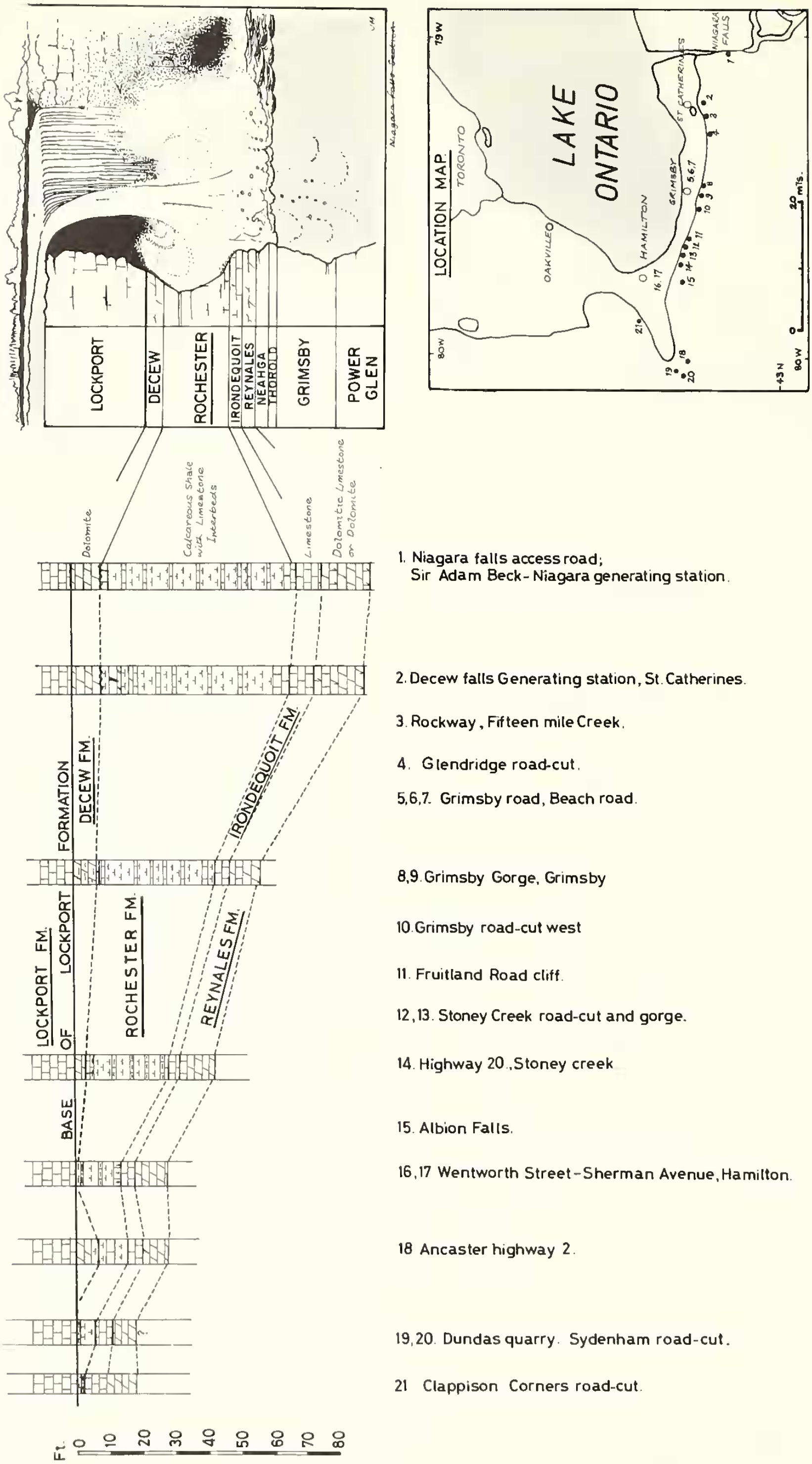

TEXT-FIG. 1. Columnar sections of the Rochester and adjacent formations exposed along the Niagara Escarpment in southern Ontario.

which cut off wave action and resulted in lagoonal conditions in eastern West Virginia, while the presence of rich marine fauna in other parts of West Virginia and Pennsylvania suggest the temporary removal of barriers and hence open marine conditions.

PREVIOUS WORK ON PALAEOZOIC ACRITARCHS OF SOUTH-WESTERN ONTARIO AND WESTERN NEW YORK

White (1862, p. 385) reported a variety of acritarchs from Silurian nodules in central and western New York. He identified these as *Zanthidia*, the sporangia of desmids and gemmules of sponges. However, they were neglected and forgotten in North America for 73 years, until Laird (1935, p. 256) again discovered *Xanthidia* in the Lockport Formation (Middle Silurian) of Ontario. Baschnagel (1942, p. 1) reported acritarchs from the Onondaga Chert (Devonian) of central New York. He assigned them to genera and families of freshwater algae. Fisher (1953, p. 13) reported a number of acritarchs from thin-sections of the Neagha and Maplewood Shale in New York. He regarded them to be zygospores of brown algae and compared some of his forms with those reported by Deflandre (1946) from the Silurian of France.

The first major contribution was made by the French palynologist Deunff (1954*a*, 1955, 1957). He made the first taxonomic studies on some of the Devonian acritarchs of Canada. Recent studies by Staplin *et al.* (1965) and Loeblich (1970) are mainly of taxonomic importance. But Cramer (1968, 1970, 1970*b*) made the first attempt to use acritarchs in Lower Palaeozoic stratigraphy and correlation.

MATERIAL AND METHODS

Channel samples from the Rochester Formation used in the present investigation consist of dark grey to black fissile calcareous shale, in part dolomitic, and argillaceous grey limestone.

Localities are designated according to the Silurian section numbers (see Map I) given by Bolton (1957). Maximum thickness of the Rochester Formation is given at the end of each locality name.

Locality 1.	Niagara Falls, access road, Sir Adam Beck-Niagara generating station, 60 feet.
ROC.1	Basal part of the section, Calcareous Shale, 20 feet.
ROC.2692	Basal part of the section, Calcareous Shale on the American side of the Niagara generating station (sample provided by Geology Department, Sheffield University).
ROC.2	Middle part of the section, Calcareous Shale, 20 feet.
ROC.2691	Middle part of the section, Calcareous Shale, location same as ROC.2692.
ROC.7	Upper part of the section, Calcareous Shale, 20 feet.
ROC.2690	Upper part of the section, Calcareous Shale, location same as ROC.2692.
Locality 2.	DeCew Falls Generating station, St. Catherines, 56 feet (locality 1 of Bolton, 1957).
ROC.15	Basal part of the section, Calcareous Shale thin limestone, 20 feet.
ROC.16	Middle part of the section, thin bedded limestone and Calcareous Shale, 20 feet.
ROC.17	Upper part, Calcareous Shale, massive limestone, 16 feet.
Locality 14.	Highway 20, Stoney Creek, 24 feet.
ROC.8	Basal part limestone, Calcareous Shale, 12 feet.
ROC.9	Upper part, Calcareous Shale with gypsum, 12 feet.
Locality 16.	Jolly Cut, Hamilton, 13 feet.
ROC.11	Basal part, Calcareous Shale, 7 feet.
ROC.10	Upper part, Calcareous Shale, 6 feet.

Locality 18.	Ancaster, Highway 2, 9 feet.
ROC.5	Basal part, Calcareous Shale, 4·5 feet.
ROC.4	Upper part, Calcareous Shale, 4·5 feet.
Locality 19, 20.	Dundas Quarry, Sydenham road-cut, 5 feet.
ROC.43007	Calcareous Shale 4 to 4·5 feet.
Locality 21.	Clappison Corners road-cut, 2·4 feet.
ROC.6	Calcareous Shale, 2·4 feet.
ROC.12	Calcareous Shale, 2 feet (250 feet east of sample ROC.6).

Apart from those from the Rochester Formation, additional samples studied and reported in the present study are as follows:

(i) Ilion Shale (Wenlockian) Utica, New York. Three samples collected from the type area are from south branch of Moyer Creek, Utica, New York. The reader is referred to Zenger (1965, p. 191, section 166) for stratigraphic details of this section. All shale samples yield an abundant microplankton flora characterized by an excellent state of preservation.

(ii) Högklint Shale (Wenlockian) Snäckgardsbaden, Visby, Sweden. One productive sample used is from a Korpklint Bay on the north side of Snäckgardsbaden, five kilometres along the coast north of Visby. The sample comes from behind a small marine swimming pool (material and stratigraphic information provided by Dr. D. Owen of the Manchester University Museum, England).

Standard chemical techniques were employed, similar to those described by Cramer (1970) for the extraction of organic-walled micro-fossils. Most of the specimens were examined at ×400 magnification. All acritarch figures are housed in the micropalaeontological collection of the Geological Survey of Canada in Ottawa. Each specimen is recorded with east–west and north–south mechanical-stage readings of Vickers Photomicroscope M-15.

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SYSTEMATIC PALAEONTOLOGY

The following list of all acritarch species identified follows the morphographic classification of Downie *et al.* (1963). Most of the species are illustrated in the plates but only those asterisked are described below. All the new taxa are based on a minimum of 25 specimens. Table 1 shows the number of specimens counted in each sample. All slides are deposited with the Palaeontological Division of the Geological Survey of Canada.

Group ACRITARCHA Evitt 1963

Subgroup NETROMORPHITAE Downie, Evitt, and Sarjeant 1963

Deunffia furcata (pl. 104, fig. 20).
D. furcata var. *niagarensis* new var. (pl. 104, fig. 14).
D. monospinosa Downie 1960 (pl. 104, fig. 8).

**D. monospinosa* var. *tonawandensis* new var. (pl. 104, figs. 4, 24).
D. ramusculosa Downie, 1960 (pl. 104, figs. 7, 15, 22).
**D. ramusculosa* var. *rochesterensis* new var. (pl. 104, fig. 18).

Domasia amphora Martin 1969 (pl. 104, figs. 9, 19).
D. bispinosa Downie 1960 (pl. 104, fig. 11).
**D. canadensis* sp. nov. (pl. 104, figs. 6, 12, 21).
D. elongata Downie 1960 (pl. 104, figs. 23, 25).
**D. rochesterensis* sp. nov. (pl. 104, figs. 2, 5).
D. trispinosa Downie, 1960 (pl. 104, fig. 1).

**Hemideunffia trifurcata* sp. nov. (pl. 104, figs. 10, 16).
Leiofusa algerensis Cramer 1970 (pl. 104, fig. 17).
L. fusiformis Eisenack 1938 (pl. 104, figs. 3, 13).
Eupoikilofusa stratifera Cramer 1964 (pl. 105, fig. 1).

Subgroup ACANTHOMORPHITAE Downie, Evitt, and Sarjeant 1963

Ammonidium cf. *A. microladum* (Downie) Lister 1970 (pl. 105, fig. 5).
Baltisphaeridium longispinosum (Eisenack) Downie 1963 (pl. 105, fig. 19).
**B. pilaris* Cramer, 1964 (pl. 105, figs. 6, 18).
**Diexallophasis denticulata* (Stockmans and Williere) Loeblich 1970 (pl. 105, fig. 3).
Elektoriskos pogonius Loeblich 1970 (pl. 105, fig. 10).
**E. simplex* sp. nov. (pl. 105, fig. 9).
**Filisphaeridium bifurcatum* sp. nov. (pl. 105, figs. 8, 12).
**Gorgonisphaeridium wenlockium* sp. nov. (pl. 105, fig. 11).
Helosphaeridium latispinosum Lister 1970 (pl. 105, fig. 16).
Micrystridium stellatum Deflandre 1945 (pl. 105, fig. 7).
Multiplicisphaeridium arbusculiferum Downie 1963 (pl. 105, figs. 4, 15).
M. eoplanktonicum (Eisenack) Lister 1970 (pl. 105, figs. 2, 14).
M. fisherii (Cramer) Lister 1970 (pl. 105, fig. 17).
Quadraditum fantasticum Cramer 1964 (pl. 105, fig. 13).
Tunisphaeridium tentaculiferum (Martin) Cramer 1970 (pl. 105, fig. 20).
Visbysphaera dilatispinosa (Downie) Lister 1970 (pl. 106, fig. 1).

Subgroup POLYGONOMORPHITAE Downie, Evitt, and Sarjeant 1963

**Evittia monterrosa* (Cramer) new comb. (pl. 106, figs. 2, 7).
E. remota (Deunff) Lister 1970 (pl. 106, fig. 4).
**Veryhachium lairdi* (Deflandare) ex-Deunff 1954 (pl. 106, figs. 5, 6).
**V. limaciforme* Stockmans and Williere 1963 (pl. 106, figs. 8, 10).
V. trispinosum Eisenack 1931 (pl. 106, fig. 9).
V. wenlockium (Downie) Downie and Sarjeant 1964 (pl. 106, fig. 3).

Subgroup HERKOMORPHITAE Downie, Evitt, and Sarjeant 1963

Cymatiosphaera octoplana Downie 1959 (pl. 106, figs. 11, 14).
C. wenlockia Downie 1959 (pl. 106, fig. 19).
Dictyotidium dictyotum (Eisenack) 1955 (pl. 106, fig. 12).

Subgroup PTEROSPERMORPHITAE Downie, Evitt, and Sarjeant 1963

Pterospermopsis cf. *P. martinii* Cramer and Cramer 1968 (pl. 106, fig. 15).
P. onondagaensis Deunff 1955 (pl. 106, figs. 16, 20).
Duvernaysphaera aranaides (Cramer) 1970 (pl. 106, fig. 18).

Subgroup SPHAEOMORPHITAE Downie, Evitt, and Sarjeant 1963

**Lophosphaeridium rugosum* sp. nov. (pl. 106, fig. 13).
**L. microgranulosum* sp. nov. (pl. 106, fig. 17).
Leiospheridia spp.
Spores *Punctatisporites* sp. rare.

TABLE 1. Numbers of specimens recorded in sample from localities 1, 14, 18, and 21 out of approximately 250 specimens counted in each sample.

	Loc. 1			Loc. 14		Loc. 18		Loc. 21
	ROC. 2692	ROC. 2691	ROC. 2690	ROC.8	ROC.9	ROC.5	ROC.4	ROC.6
Deunffia furcata	2	6	4	6	..	..	6	5
D. furcata var. *niagarensis*	1	2	3	4	3	..	2	..
D. monospinosa	5	5	5	8	..	6	2	..
D. monospinosa var. *tonawandensis*	1	2	3	4	1	4	6	..
D. ramusculosa	30	35	30	28	4	18	14	10
D. ramusculosa var. *rochesterensis*	11	3	9	12	4	4	10	2
Domasia amphora	10	7	3	2	..	2	14	..
D. bispinosa	6	4	2	6	5	6	4	..
D. canadensis	23	15	10	..	3	8	14	18
D. elongata	15	16	22	22	26	10	12	25
D. rochesterensis	12	7	5	6	..	4	4	..
D. trispinosa	21	18	16	16	17	12	8	12
Hemideunffia trifurcata	3	1	1	4	..	..	..	3
Leiofusa algerensis	9	5	3	2	..	4	6	5
L. fusiformis	6	6	4	2	7	4	4	2
E. stratifera	..	1	..	2	1	..	..	..
Ammonidium cf. *A. microcladum*	4	5	3	6	2	2	6	14
Baltisphaeridium longispinosum	15	7	6	4	8	6	6	16
B. pilaris	7	3	3	2	4	10	2	15
Diexallophasis denticulata	12	12	11	6	14	14	8	20
Elektoriskos pogonius	2	1	2	4	..	..	4	3
E. simplex	..	4	4	6	3	4	4	8
Filisphaeridium bifurcatum	1	2	..	2	2	6	4	..
Gorgonisphaeridium wenlockium	2	1	..	2	1	2	..	..
Helosphaeridium latispinosum	12	2	18	10	13	10	10	15
Micrhystridium stellatum	11	3	9	6	15	6	4	10
Multiplicisphaeridium arbusculiferum	4	5	4	2	3	8	4	8
M. eoplanktonicum	5	2	2	8	1	4	4	3
M. fisherii	6	3	4	2	?27	6	2	6
Quadraditum fantasticum	1	1	..	..	..	..	..	..
Tunisphaeridium tentaculiferum	1	..	..	2	..	4	..	..
Visbysphaera dilatispinosa	1	..	..	1	..	..	..	..

	Loc. 1			Loc. 14		Loc. 18		Loc. 21
	ROC. 2692	ROC. 2691	ROC. 2690	ROC.8	ROC.9	ROC.5	ROC.4	ROC.6
Evittia monterrosa	5	2	2	6	2	..	..	..
Evittia remota	2	2	2	..	..	4	2	5
V. lairdi	4	4	7	4	2	4	6	3
V. limaciforme	6	1	7	2	21	4	2	3
V. trispinosum	11	12	14	6	11	2	6	8
V. wenlockium	10	3	2	6	12	2	6	12
Cymatiosphaera octoplana	1	5	3	6	2	..	2	2
C. Wenlockia	3	3	1	4	..	4	2	..
Dictyotidium dictyotum	2	2	11	12	11	8	4	7
Pterospermopsis cf. *P. martinii*	2	..	1	2	..	..	..	..
P. onodagaensis	2	..	1	2	1	2	..	..
Duvernaysphaera aranaides	1	2	..	..	2	..	..	2
Lophosphaeridium rugosum	2	2	5	6	4	18	16	..
L. microgranulosum	2	1	..	2	1	..	..	..

Subgroup NETROMORPHITAE Downie, Evitt, and Sarjeant 1963

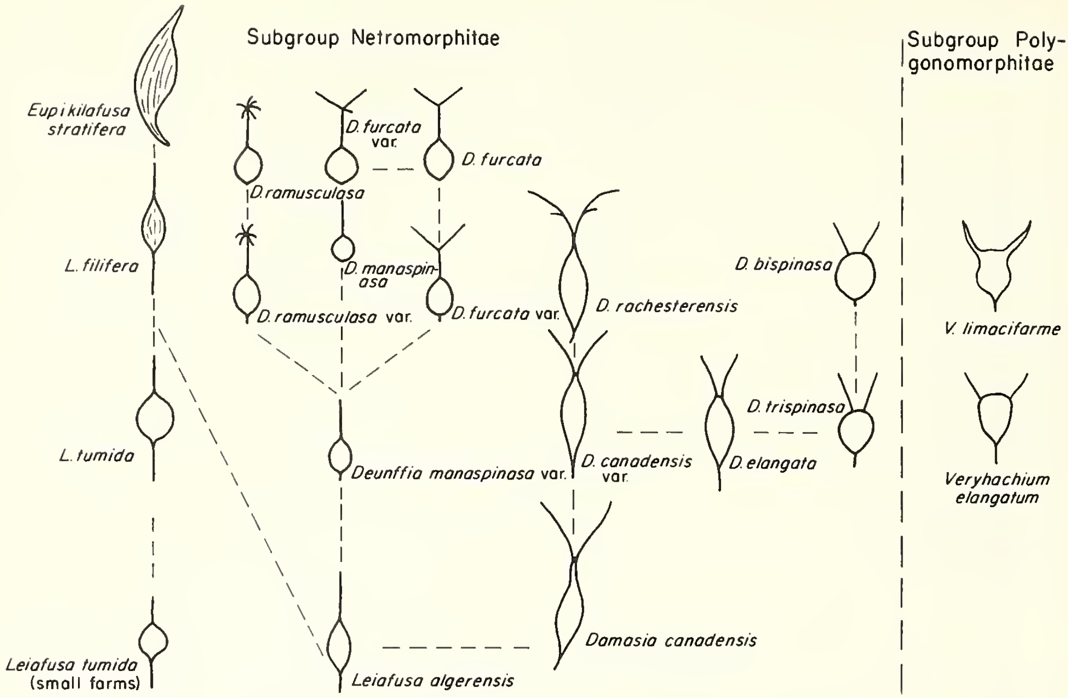
Diagnosis. Acritarchs having an elongate to fusiform test without an inner body. Surface smooth, granular, striate, spines or with large ornament. One or more spines closed distally may be present at one or both poles. Questionable openings observed in a few species.

Remarks. Well-known genera include: *Deunffia* Downie 1960; *Domasia* Downie 1960: *Leiofusa* Eisenack 1938: *Dactylofusa* Brito and Santos 1965 and *Poikilofusa* Staplin, Jansonius and Pocock 1965. These have a wide geographical distribution and are characteristic of the Silurian strata. Other genera include *Anthatractus* Deunff 1954: *Baiomeniscus* Loeblich 1970: *Disparifusa* Leoblich 1970: *Lunulidia* Eisenack 1958: *Pseudolunulidia* Brito and Santos 1965; *Leiovalia* Eisenack 1965: *Lunulidia*, *Leiovalia* and *Pseudolunulidia* are forms with close morphological relationship with *Leiofusa*. In fact the genotypes of *Lunulidia* and *Leiovalia* were originally described under *Leiofusa* (Eisenack 1938, 1951). These are relatively lesser known genera and range from the Upper Ordovician to the Lower Devonian.

Some of the netromorphs, e.g. *Domasia*, show a close morphological similarity with the polygonomorphs, for example *Veryhachium*. Downie (1963, p. 637) observed *V. elongatum* and found forms with intermediate morphology between *Veryhachium* of the *V. trispinosum*—*V. trisulcum* group, and *Domasia* of the *D. trispinosa*—*D. elongata* group. However, Downie (1963, 633–634) recognized close relationship of *Leiofusa*, *Deunffia*, and *Domasia*.

Deflandre and Deflandre (1964) removed *Deunffia* and *Domasia* from Netromorphitae, considering them simplified Polygonomorphitae.

However, Brito (1967) rejected the views of Deflandre and Deflandre and suggested a close relationship of *Deunffia*, *Domasia*, and *Leiofusa*.



TEXT-FIG. 2. Hypothetical relationship between *Leiofusa*, *Eupoikilofusa*, *Deunffia*, and *Domasia* of subgroup Netromorphitae and distinction between *Domasia* and *Veryhachium* (subgroup Polygonomorphitae).

This writer shares the views of Downie (1963) and Brito (1967) on possible relationship of some Netromorphs. Some of the Rochester acritarchs seem critical to demonstrate a relationship between *Leiofusa*, *Deunffia*, *Domasia* and *Eupoikilofusa* (text-fig. 2). Further, this writer believes that *Lunulidia*, *Leiovalia* are forms with close morphological relationship with *Leiofusa*.

Undoubtedly some of the Netromorphs, in particular species of *Domasia* are intermediate in morphology with Polygonomorphs, for example *Veryhachium elongatum*. However, examination of hundreds of specimens show two fundamental characters on which species of *Domasia* and *Veryhachium* can be separated.

1. *Veryhachium* spp. are distinctly polygonal, and processes always leave the vesicle from the corners. *Domasia* spp. have an elongate to fusiform vesicle and processes are generally located near the poles of the vesicle.

2. *Domasia* spp. are always with septate processes; in *Veryhachium* this feature is extremely rare.

Genus DEUNFFIA Downie 1960 emend.

Type species. Deunffia monospinosa Downie 1960. Middle Silurian, England.

Original diagnosis. Vesicle hollow, elongate ellipsoidal, more or less smooth, less than 100 μ in length. Body composed of thin, pale yellow to brown, organic membrane. Ornament consisting of a single hollow spine situated at one end. Spine terminates in a point or branches in various ways.

The above-mentioned diagnosis is emended to include:

1. Ornament consisting of one or two hollow processes situated at opposite ends. The long process terminates in a point or branches in various ways, other process is short and terminates in a point and does not exceed more than a few microns.

2. The 100 μ length limit is removed to include larger forms.

Deunffia furcata var. *niagarensis* new var.

Plate 104, fig. 14

Holotype. GSC No. 31615, locality 14, sample ROC.9, Slide No. 9/C.

Remarks. *D. furcata* var. *niagarensis* differs from *D. furcata* by the presence of a small spine at the opposite end of the main shaft.

Dimensions. Size of the vesicle 18 μ (range, 16–18 μ); width of the vesicle 12 μ (range, 10–13 μ); length of the main shaft 16 μ (range, 14–16 μ); length of the small process 1 μ (range, 1–2 μ).

Deunffia monospinosa var. *tonowadensis* new var.

Plate 104, figs. 4, 24

Type specimens. Holotype GSC No. 31609, locality 21, sample ROC.12, Slide No. 12/a; paratype GSC No. 31609a, locality 18, sample ROC.4, Slide No. 4/A.

Remarks. This variety differs from *D. monospinosa* by the presence of a small spine at the opposite end of the main shaft, and from *L. alegerensis* by a much smaller spine.

Dimensions. Size of the vesicle 18 μ (range, 16–24 μ); width of the vesicle 9 μ (range, 7–11 μ); length of the main shaft 60 μ (range, 50–75 μ); length of the small process 8 μ (range, 6–8 μ).

Deunffia ramusculosa var. *rochesterensis* new var.

Plate 104, fig. 18

Holotype. GSC No. 31618, locality 1, sample ROC.1, Slide No. 1/B.

Remarks. This species differs from *D. ramusculosa* by the presence of a small process (3–4 μ) opposite to the end of the long shaft. Where the process is broken, a small hole or an opening is observed. However, where the vesicle is squashed or folded, *D. ramusculosa* may be confined with *D. ramusculosa* var. *rochesterensis*.

Genus DOMASIA Downie 1960

Type species. *Domasia trispinosa* Downie 1960. Middle Silurian, England.

Diagnosis. Vesicle hollow, elongate, ellipsoidal more or less smooth, about 20 μ in length. Body composed of pale yellow to brown organic membrane. Ornament consisting of two relatively long hollow spines arising near one pole and a single spine of variable length at the opposite end.

Remarks. The two processes arising near one pole may bifurcate at the tips, or a thin hairy process may arise from the middle of the spine. *D. elongata*, *D. trispinosa*, *D. bispinosa*, and *D. amphora* are morphologically very closely related species. However, the nature of the entrance of the processes into the vesicle seems to differentiate these species. *D. elongata* and *D. amphora* have processes merging before entering the vesicle, while *D. trispinosa* and *D. bispinosa* have processes entering the vesicle separately. The Rochester acritarchs show a wide variety of transional forms between *D. elongata* and *D. amphora*: Downie (1963, p. 637) records a transition between *D. elongata* and *D. trispinosa*.

Domasia canadensis sp. nov.

Plate 104, figs. 6, 12, 21

Type specimens. Holotype GSC No. 31610, locality 1, sample ROC.1, Slide No. 1/B; Paratypes GSC No. 31610a–b, locality 1, sample ROC.1, Slide No. 1/A, 1/E.

Description. Vesicle fusiform, pale, smooth or faintly granulose. One pole tapering at first into a stretched, unseptate neck, which is drawn out into two processes. Other pole tapers and terminates into one short process.

EXPLANATION OF PLATE 104

All figures ×500 and from unretouched negatives.

Fig. 1. *Domasia trispinosa* Downie 1960, GSC No. 31606, locality 14, sample ROC.8, slide number 8/E.

Figs. 2, 5. *D. rochesterensis* sp. nov. 2, holotype GSC No. 31607, locality 1, sample ROC.1, slide number 1/C. 5, paratype GSC No. 31607a, locality 1, sample ROC.1, slide number 1/B.

Figs. 3, 13. *Leiofusa fusiformis* Eisenack 1938, GSC Nos. 31608 a–b, 3, locality 1, sample ROC.1, slide number 1/A. 13, locality 21, sample ROC.12, slide number 12/A.

Figs. 4, 24. *Deunffia monospinosa* var. *tonawandensis* new var. 4, holotype GSC No. 31609, locality 21, sample ROC.12, slide number 12/A. 24, paratype GSC No. 31609a, locality 18, sample ROC.4, slide number 4/A.

Figs. 6, 12, 21. *D. canadensis* sp. nov. 6, holotype GSC No. 31610, locality 1, sample ROC.1, slide number 1/B. 12, 21, paratypes GSC No. 31610 a–b, locality 1, sample ROC.1, slide numbers 1/A, 1/E.

Figs. 7, 15, 22. *Deunffia ramusculosa* Downie 1960, GSC Nos. 31611 a–c. 7, locality 21, sample ROC.12, slide number 12/A. 15, locality 14, sample ROC.8, slide number 8/A. 22, locality 1, sample ROC.1, slide number 1/A.

Fig. 8. *D. monospinosa* Downie 1960, GSC No. 31612, locality 1, sample ROC.1, slide number 1/C.

Figs. 9, 19. *Domasia amphora* Martin 1969, GSC No. 31613. 9, locality 18, sample ROC.5, slide number 5/A. 19, locality 1, sample number ROC.1, slide number 1/B.

Figs. 10, 16. *Hemideunffia trifurcata* sp. nov. 10, holotype GSC No. 31614, locality 1, sample ROC.1, slide number 1/C. 16, paratype GSC No. 31614a, locality 1, sample number ROC.2691, slide number 2691/A.

Fig. 11. *Domasia bispinosa* Downie 1960, holotype 31615, locality 14, sample ROC.8, slide number 8/E.

Fig. 14. *Deunffia furcata* var. *niagarensis* new var., holotype GSC No. 31615, locality 14, sample ROC.9, slide number 9/C.

Fig. 17. *Leiofusa algerensis* Cramer 1970, GSC No. 31617, locality 1, sample ROC.1, slide number 1/F.

Fig. 18. *Deunffia ramusculosa* var. *rochesterensis* new var. Holotype GSC No. 31618, locality 1, sample ROC.1, slide number 1/C.

Fig. 20. *D. furcata* Downie 1960, GSC No. 31619, locality 1, sample ROC.1, slide number 1/E.

Figs. 23, 25. *D. elongata* Downie 1960, GSC No. 31620 a–b, locality 1, sample ROC.1, slide number 1/B.

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Remarks. D. candensis sp. nov. differs from *D. amphora* by the presence of a distinct unseptate and stretched neck. In *D. amphora*, the vesicle terminates into a small neck, but a sharp break is present between the neck and the vesicle.

Dimensions. Length of the vesicle 36 μ (range, 32–40 μ); width of the vesicle 7 μ (range, 6–10 μ); length of the long processes 41 μ (range, 39–45 μ); length of the short process 13 μ (range, 9–15 μ); length of the neck 3–4 μ (range, 3–7 μ).

Domasia rochesterensis sp. nov.

Plate 104, figs. 2, 5

Type specimens. Holotype GSC No. 31607, locality 1, sample ROC.1, Slide No. 1/C, Paratype GSC No. 31607a, locality 1, sample ROC.1, Slide No. 1/8.

Description. Vesicle hollow, fusiform, pale yellow, smooth. Two long processes arise near one pole. Each process gives rise to a short secondary process at about the mid-length. A single short process present at the opposite end. Processes septate.

Remarks. The presence of a short secondary process arising from the long processes differentiates this species from *Domasia elongata.*

Dimensions. Size of the vesicle 24–34 μ (range, 20–38 μ); width of the vesicle 8–10 μ (range, 7–12 μ); length of the long processes 33 μ (range, 30–45 μ); length of the secondary processes 5–7 μ (range, 4–7 μ); length of the short process 15–17 μ (range, 12–20 μ).

Genus HEMIDEUNFFIA gen. nov.

Type species. Hemideunffia trifurcata sp. nov.

Diagnosis. Vesicle highly elongate, tapering, pale yellow, thin, smooth walled; one pole simple; opposite pole terminates into three processes, processes may be closed or open at the distal end, septate processes may be present.

Remarks. This genus differs from *Leiofusa* by the presence of a trifurcate process at one pole, and from *Deunffia* by the presence of a long, tapering vesicle. Indeed, this genus is intermediate between *Leiofusa* and *Deunffia.*

Hemideunffia trifurcata sp. nov.

Plate 104, figs. 10, 16

Type specimens. Holotype GSC No. 31614, locality 1, sample ROC.1, Slide No. 1/C; Paratype GSC No. 31614a, locality 1, sample ROC.2691, Slide No. 2691/A.

Description. Visicle highly elongate, fusiform, tapering, smooth thin walled, pale transparent, fragile often compressed, twisted or folded; one pole simple; opposite pole terminates into a trifurcate process, processes generally closed at the tips, non-septate.

Dimensions. Length of the vesicle 70 μ (range, 65–85 μ); width of the vesicle 4–8 μ (range, 4–10 μ); length of the processes 9 μ (range, 6–10 μ).

Genus BALTISPHAERIDIUM (Eisenack 1958), emend, Downie and Sarjeant 1963, emend.

Type species. Ovum hispidium longispinosum Eisenack 1931, Baltic, Ordovician.

Remarks. In this work *Baltisphaeridium* is accepted in a broad sense as amended by Downie and Sarjeant (1963) but is restricted to include forms with predominantly homomorphic, unbranched processes, closed or open to the vesicle cavity. Forms with hetromorphic nature of the process termination, and free communication of the process with vesicle, are transferred to *Multiplicisphaeridium.* Processes with equifurcate termination at the tips is transferred to *Ammonidium.* Forms in which processes communicate freely with the vesicle and without any tendency for the processes to close off at its junction with the central body are transferred to *Diexallophasis.* Forms in which the central body is ornamented by numerous prominent pila, rather being smooth or with minor ornamentation are considered to belong to *Piliferosphaera*, and forms in which processes are very short and terminate in a point or in short bifurcations with a feather or rosette of small spines, just below their distal end are considered to belong to *Tylotopalla.*

Baltisphaeridium pilaris Cramer 1964

Plate 104, figs. 6, 18

1970 *Baltisphaeridium pilaris* var. typicum Cramer, p. 166, pl. 18, figs. 55d–h (gives detailed synonymy).
1970 *Cymbosphaeridium pilar* (Cramer) Lister, p. 63, figs. 256–266.

Remarks. The branching of *B. pilaris* is very complex and considerable variation exists within a species. However, in *B. pilaris* var. *typicum*, the cauliflorate terminations of the processes is seen in most of the specimens studied. *B. pilaris* was transferred by Lister (1970, p. 64) to a new genus *Cymbosphaeridium.* This genus is primarily based on the 'reflected plate formula' proposed by Lister (1970, p. 63–65). This writer does not believe in creating new form-genera on hypothetical characteristics, drawn from the reconstruction of hypothetical thecae of acritarchs. Indeed, such study is important to understand the phylogenetic relationship of acritarchs, but not for creating new genera in a morphographic system of classification.

Diexallophasis denticulata (Stockmans and Williere) Loeblich 1970

Plate 105, fig. 3

1963 *Diexallophasia denticulata* (Stockmans and Williere) Loeblich, p. 715, figs. 8 A–E, 9 A–C.
1963 *Baltisphaeridium denticulatum* Stockmans and Williere, p. 458, pl. 1, fig. 4.
1970 *Baltisphaeridium denticulatum* Cramer, pp. 136–138.
1965 *Baltisphaeridium denticulatum* Martin, p. 5, pl. 1, figs. 5, 6, text-figs. 5, 6.
1966 *Baltisphaeridium denticulatum* Martin, p. 309.
1968 *Baltisphaeridium denticulatum* Jardine and Yapoudjian, pl. 3, fig. 26.
1963 *Baltisphaeridium granulatispinosum* Downie, p. 640, pl. 9, figs. 1, 7.
1966 *Baltisphaeridium granulatispinosum* Martin, p. 310, pl. 1, fig. 24.
1968 *Baltisphaeridium granulatispinosum* Martin, p. 48, pl. 3, fig. 127, pl. 4, fig. 186, pl. 7, fig. 310, pl. 8, figs. 360, 362.
1970 *Evittia granulatispinosa* Lister, p. 67, pl. 4, figs. 2, 3, 5–9, 12, pl. 5, fig. 2: text-figs. 170, 20b.

Remarks. Cramer (1970, pp. 138–140) describes five varieties of *D. denticulata* (*B. denticulatum*). However, Lister (1970, p. 68) and the present writer recognize extreme variability in this group. The character of spines and ornament is continuously variable, thus encouraging the use of this species in a broad sense.

Diexallophasis granulatispinosum (= *Baltisphaeridium granulatispinosum*) is regarded as a junior synonym of *D. denitculata* (= *Baltisphaeridium denticulatum*). However, Lister (1970, p. 68) recognized *Evittia granulatispinosa* (*B. granulatispinosum*) as a valid taxon, and states 'in view of the fact that the process tips of the holotype of *denticulatum* are missing and the character of the process tips is essential to the diagnosis of any species of *Evittia*, the specific name *denticulatum* is considered to be *nomen dubium*'. But the present author rejects the transfer of *denticulatum* to genus *Evittia* for the reasons stated on p. 815, and recognizes the transfer of *denticulatum* in *Diexallophasis*. The diagnosis of *Diexallophasis* broadly defines the character of tips, and hence would not warrant the rejection of the holotype of *denticulatum* because of the missing tips.

Genus ELEKTORISKOS Loeblich 1970

Type species. *Elektoriskos auora* Loeblich 1970, Middle Silurian Maplewood Shale, New York.

Diagnosis. Circular to subcircular central body, wall apparently single layered,

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EXPLANATION OF PLATE 105

All figures ×500 and from unretouched negatives.

Fig. 1. *Eupoikilofusa stratifera* Cramer 1964, GSC No. 31621, locality 14, sample ROC.8, slide number 8/B.

Figs. 2, 14. *Multiplicisphaeridium eoplanktonicum* Downie 1963, GSC Nos. 31622 a–b. 2, locality 1, sample ROC.1, slide number 1/A. 14, locality 18, sample ROC.5, slide number 5/A.

Fig. 3. *Diexallophasis denticulata* (Stockmans and Williere) Loeblich 1970. GSC No. 31623, locality 1, sample ROC.1, slide number 1/A.

Figs. 4, 15. *M. arbusculiferum* Downie 1963, GSC Nos. 31624 a–b. 4, locality 16, sample ROC.11, slide number 11/B. 15, locality 14, sample ROC.8, slide number 8/A.

Fig. 5. *Ammonidium* cf. *A. microcladum* (Downie) Lister 1970, GSC No. 31626.

Figs. 6, 18. *Baltisphaeridium pilaris* Cramer 1964, GSC Nos. 31626. 6, locality 1, sample ROC.2690, slide number 2690/A. 18, locality 21, sample ROC.12, slide number 12/A.

Fig. 7. *Micrhystridium stellatum* Deflandre 1945, GSC No. 31627, locality 14, sample ROC.8, slide number 8/B.

Figs. 8, 12. *Filisphaeridium bifurcatum* sp. nov. 8, holotype GSC No. 31628, locality 1, sample ROC.1, slide number 1/C. 12, paratype GSC No. 31628a, locality 14, sample ROC.8, slide number 8/A.

Fig. 9. *Elektoriskos simplex* sp. nov., holotype GSC No. 31629, locality 18, sample ROC.5, slide number 5/A.

Fig. 10. *E. pogonius* Leoblich 1970, GSC No. 31630, locality 1, sample ROC.1, slide number 1/A.

Fig. 11. *Gorgonisphaeridium wenlockium* sp. nov., holotype GSC No. 31631, locality 14, sample ROC.8, slide number 8/A.

Fig. 13. *Quadraditum fantisticum* Cramer 1964, GSC No. 31632, locality 1, sample ROC.2691, slide number 2691/A.

Fig. 16. *Helosphaeridium latispinosum* Lister 1970, GSC No. 31633, locality 21, sample ROC.12, slide number 12/A.

Fig. 17. *M. fisherii* (Cramer) Lister 1970, GSC No. 31634, locality 14, sample ROC.8, slide number 8/A.

Fig. 19. *B. longispinosum* Downie 1963, GSC No. 31635, locality 1, sample ROC.1, slide number 1/A.

Fig. 20. *Tunisphaeridium tentaculiferum* (Martin) Cramer 1970, GSC No. 31636, locality 6, sample ROC.12, slide number 12/A.

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psilate, chagrenate to granulate with numerous slender, flexible but solid processes which do not communicate with the interior of the central body.

Remarks. This genus differs from *Comasphaeridium* in lacking the densely crowded hair-like processes and from *Filisphaeridium* in lacking the distal differentiation of the processes.

Elektoriskos simplex sp. nov.

Plate 105, fig. 9

1970 *Elektoriskos* sp. Loeblich, p. 719, fig. 13c.

Holotype. GSC No. 31629, locality 18, sample ROC.5, Slide No. 5/A.

Description. Vesicle rounded to spherical, thin, smooth, numerous (30–40) short, solid processes, without communicating with vesicle.

Remarks. E. simplex sp. nov. differs from *E. sequestratus* Loeblich by the absence of small grana on the vesicle.

Genus FILISPHAERIDIUM Staplin, Jansonius and Pocock 1965

Type species. Micrhystridium setasessitante Jansonius 1962, Lower Triassic, Alberta, Canada.

Filisphaeridium bifurcatum sp. nov.

Plate 105, figs. 8, 12

Type specimens. Holotype GSC No. 31628, locality 1, sample ROC.1, Slide No. 1/C; Paratype GSC No. 31628a, locality 14, sample ROC.8, Slide No. 8/A.

Description. Vesicle ellipsoidal to subspherical, smooth, processes 30 or more short tapering about 10% of the vesicle, bifurcating at the tips, process communicate freely with the vesicle.

Remarks. F. bifurcatum sp. nov. differs from *F. brevispinosum* Lister by the presence of bifurcating tips.

Dimensions. Size of the vesicle 27–36 μ (range, 25–38 μ); length of the process 3–5 μ (range, 3–5 μ).

Genus GORGONISPHAERIDIUM Staplin, Jansonius and Pocock 1965

Type species. Gorgonisphaeridium winslowii Staplin, Jansonius and Pocock 1965, Lower Carboniferous, Southern Alberta, Canada.

Gorgonisphaeridium wenlockium sp. nov.

Plate 105, fig. 11

Holotype. GSC No. 31632, locality 14, sample ROC.8, Slide No. 8/A.

Description. Vesical spherical, wall firm and thick, brownish, numerous short spines (30–40) with bulbous base and pointed tip, processes communicate freely with vesicle.

Remarks. This species differs from *G. spicatum* (Staplin) by its larger size, and pointed tips.

Dimensions. Size of the vesicle 80 μ (range, 70–82 μ); length of the spines 6–16 μ (range, 5–18 μ); width of the spines at the base 5–6 μ (range, 5–6 μ); distance between the spines 9–13 μ (range, 9–13 μ).

Genus EVITTIA Brito 1967

Type species. *Evittia sommeri* Brito 1967. Lower Devonian, Brazil.

Restricted diagnosis. Vesicle triangular to polygonal like *Veryhachium* but with the processes typically ramified, vesicle wall and processes sculptured.

Remarks. Cramer (1970, p. 47) considered *Evittia* a partial junior synonym of *Baltisphaeridium* on the grounds that the basal portion of the processes and their number strongly influence the shape of the vesicle. This is possible if *Evitta* possessed many processes. But Brito's generic diagnosis mentions '. . . having a general structure of Veryhachium . . .' which in addition to a triangular or polygonal vesicle shape also puts a limit on the number of the processes. In fact the Subgroup Polygonomorphitae to which *Evittia* belongs is characterized by a low-number of processes.

Lister (1970, p. 66) emended *Evittia*, and broadened the genus to include subspherical acanthomorph species of *Baltisphaeridium* thus greatly departing from Brito's original intentions. It should be noted that *Evittia* like *Veryhachium* is defined on subgroup basis by a combination of shell shape and low spine number. Thus introducing within this genus subspherical species regardless of spine number is rejected as contrary to the original intention of Brito.

Evittia monterrosa (Cramer) nov. comb.

Plate 106, figs. 2, 7

1969 *Baltisphaeridium monterrosae* Cramer, p. 490, pl. 1, figs. 5–7.
1970 *Baltisphaeridium monterrosae* Cramer, p. 129, pl. 8, figs. 127–135.

Remarks. The basis for the transfer of this species to *Evittia* is the presence of a polygonal vesicle with a small number of processes (2–5), bifurcating or trifurcating at the distal end.

Genus VERYHACHIUM Deunff 1954, emend. Downie and Sarjeant 1963

Veryhachium lairdi (Deflandre) Deunff 1954

Plate 106, figs. 5, 6

1946 *Hystrichosphaeridium lairdi* Deflandre, card 1112.
1954 *Veryhachium lairdi* Deunff, p. 306.
1963 *Veryhachium lairdi* Stockmans and Williere, p. 454, pl. 4, fig. 5.
1964 *Veryhachium lairdi* Cramer, p. 309, pl. 11, fig. 16.
1965 *Veryhachium lairdi* Martin, pp. 13–14, figs. 14–15.
1969 *Veryhachium lairdi* Martin, p. 95, pl. 2, figs. 75–83.
1970 *Veryhachium lairdi* Loeblich, p. 741.

Remarks. V. lairdi has a maximum of five processes. However a single specimen shown on Plate 106, figs. 5–6 contains six processes and is provisionally placed with the specimens of *V. lairdi.*

Veryhachium limaciforme Stockmans and Williere 1963

Plate 106, figs. 8, 10

1963 *Veryhachium limaciforme* Stockmans and Williere, p. 433, pl. 1, figs. 12, 14, 15, 19.
1965 *Veryhachium limaciforme* Martin, p. 22, fig. 21.
1969 *Veryhachium limaciforme* Martin, p. 96, pls. 7, 8, figs. 354, 402.
1963 *Veryhachium elongatum* Downie, p. 637, pl. 92, fig. 10.
1963 *Veryhachium delmeri* Stockmans and Williere, p. 453, pl. 1, fig. 17.
1965 *Veryhachium delmeri* Martin, p. 22, fig. 22.
1966 *Veryhachium delmeri* Martin, p. 316.
1969 *Veryhachium delmeri* Martin, p. 90, pls. 4, 6, figs. 176, 346–347.
1970 *Domasia limaciforme* (Stockmans and Williere) Cramer, p. 68, pl. 1, figs. 16, 27, 28.

Remarks. This species is retained in the genus *Veryhachium* on three counts: 1. A highly elongate, triangular vesicle. 2. The attachment of the processes to the corners of the vesicle. 3. Absence or very rare septate processes, unlike the species of *Domasia.*

EXPLANATION OF PLATE 106

All figures × 500 and from unretouched negatives.

Fig. 1. *Visbysphaera dilatispinosa* (Downie) Lister 1970, holotype GSC No. 31637, locality 14, sample ROC.8, slide number 8/A.

Figs. 2, 7. *Evittia monterrosa* (Cramer) new comb. GSC Nos. 31638 a–b. 2, locality 1, sample ROC.1, slide number 1/A. 7, locality 14, sample ROC.8, slide number 8/A.

Fig. 3. *Veryhachium wenlockium* (Downie) Downie and Sarjeant 1964, GSC No. 31639, locality 1, sample ROC.1, slide number 1/B.

Fig. 4. *E. romota* (Deunff) Lister 1970, GSC No. 31640, locality 18, sample ROC.5, slide number 5/A.

Figs. 5, 6. *V. lairdi* (Deflandare) ex-Deunff 1954, GSC Nos. 31641 a–b. 5, locality 14, sample ROC.9, slide number 9/A. 6, locality 1, sample ROC.1, slide number 1/A.

Figs. 8, 10. *V. limaciforme* Stockmans and Williers 1963, GSC Nos. 31642 a–b. 8, locality 14, sample ROC.8, slide number 8/E. 10, slide number 8/A.

Fig. 9. *V. trispinosum* Eisenack 1931, GSC No. 31643, locality 1, sample ROC.1, slide number 1/A.

Figs. 11, 14. *Cymatiosphaera octoplana* Downie 1959, GSC Nos. 31644 a–b. 11, locality 14, sample ROC.8, slide number 8/B. 14, slide number 8/A.

Fig. 12. *Dictyotidium dictyotum* (Eisenack) 1955, GSC No. 31645, locality 1, sample ROC.1, slide number 1/G.

Fig. 13. *Lophosphaeridium rugosum* sp. nov., holotype GSC No. 31646, locality 18, sample ROC.5, slide number 5/A.

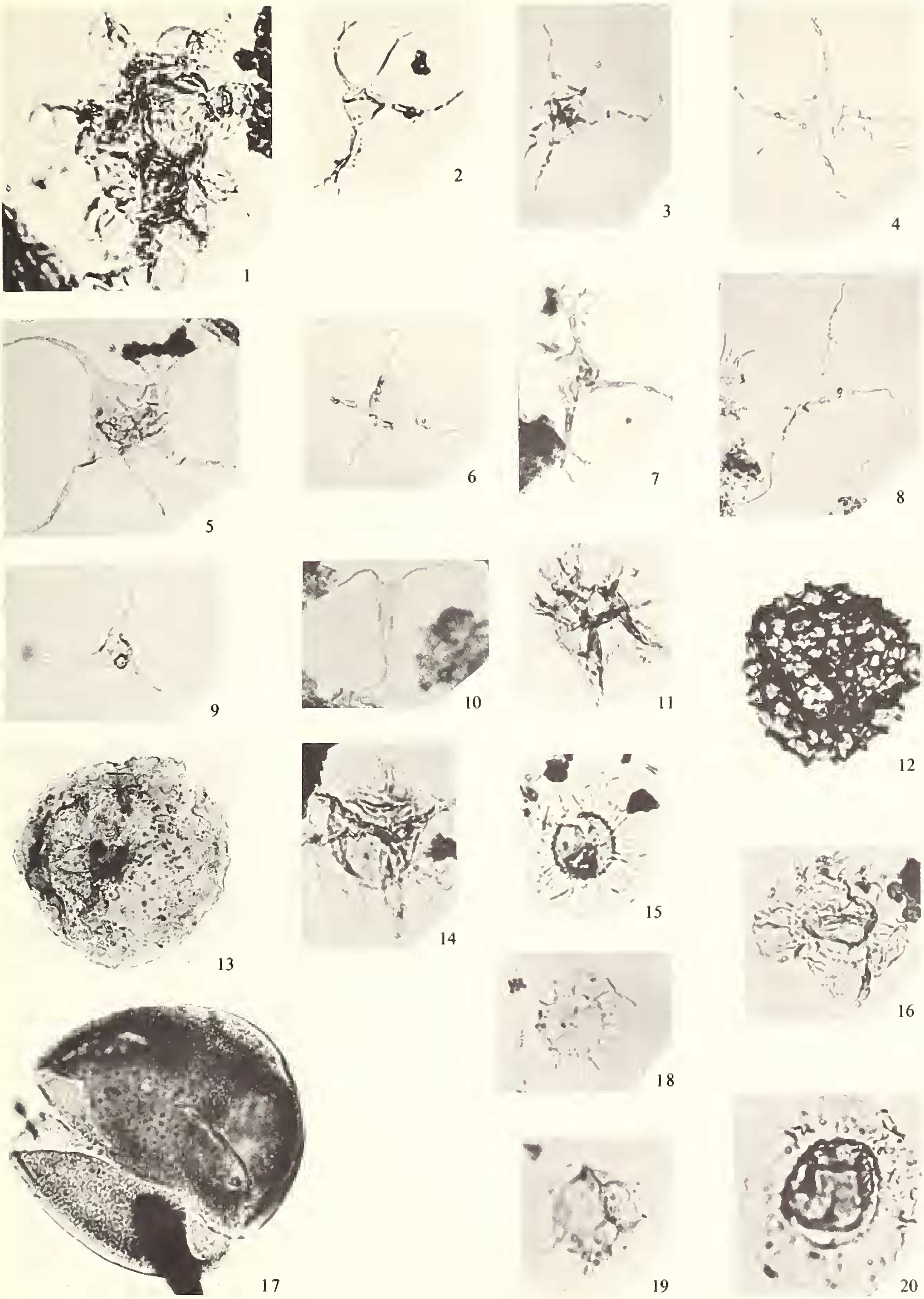
Fig. 15. *Pterospermopsis* cf. *P. martinii* Cramer & Cramer 1968, GSC No. 31647, locality 1, sample ROC.1, slide number 1/C.

Figs. 16, 20. *P. onondagaensis* Deunff 1955, GSC Nos. 31648 a–b. 16, locality 8, sample ROC.8, slide number 8/A. 20, locality 1, sample ROC.1, slide number 1/A.

Fig. 17. *L. micrograntulosum* sp. nov., holotype GSC No. 31649, locality 14, sample ROC.8, slide number 8/A.

Fig. 18. *Duvernaysphaera aranaides* (Cramer) 1970, GSC No. 31650, locality 1, sample ROC.1, slide number 1/C.

Fig. 19. *C. wenlockia* Downie 1969, GSC No. 31651, locality 1, sample ROC.1, slide number 1/E.



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Genus LOPHOSPHAERIDIUM Timofeyev 1959

Type species. Lophosphaeridium rarum Timofeyev, designated by Downie (1963), Ordovician, Russia.

Lophosphaeridium rugosum sp. nov.

Plate 106, fig. 13

Holotype. GSC No. 31646, locality 18, sample ROC.5, Slide No. 1/G.

Description. Vesicle rounded, orange yellow, thick walled, verrucose ornament, often in crescentric pattern.

Remarks. This species could be an alete spore.

Dimension. 120–130 μ.

Lophosphaeridium micrograriulosum sp. nov.

Plate 106, fig. 17

Holotype. GSC No. 31649, locality 14, Sample ROC.8, Slide No. 8/A.

Description. Vesicle rounded, orange yellow, wall thick, finely granulose, granules closely packed, giving the appearance of a finely meshed network.

Dimensions. 160 μ.

DISCUSSION OF THE MICROFLORA

Age of the Rochester Microflora. The presence of highly evolved netromorphs of the *Deunffia* complex (*Deunffia ramusculosa*, *D. furcata*) in the Rochester Formation allows correlation with the Buildwas Beds in Shropshire (Downie 1963). On this basis the Rochester microflora is assigned a Lower Wenlockian age.

Intracontinental comparisons

Power Glen Formation (*Lower Llandovery*), *Niagara Gorge*, *southern Ontario and New York State*. The Rochester acritarchs reported from the Power Glen Formation (Cramer and Cramer 1970) belong to the *Diexallophasis denticulata* and *Veryhachium trispinosum* complex (Table 2). These are forms ranging from the Upper Llandovery to the Emsian.

Neagha and Maplewood Shales (*Upper Llandovery*) *of New York State*. The Rochester acritarchs present in these shales (Table 2) are dominantly long-ranging species (Llandovery/Ludlow) also. However, *Baltisphaeridium neagha*, *Dactylofusa neagha*, *Neoveryhachium carminae*, and *Carminella maplewoodensis* reported by Cramer and Cramer (1970, p. 713) and *Elektoriskos aurora*, *Holothuriadeigma heterakanium*, and *Multiplicisphaeridium mergaeferum* reported by Loeblich (1970) in the Neagha Shale were not found in the Rochester Formation.

Loeblich (1970) reported a number of species from the Maplewood Shale, in particular *Baimeniscus granulatus*, *Diexallophasis caperoradiola*, *Estiastra stellata*, and species of *Elektoriskos* and *Leiofusa*. Furthermore, both Cramer and Cramer (1970) and Loeblich (1970) record the presence of *Neoveryhachium carminae* and *Carminella*

TABLE 2. Selected acritarch species in the Rochester Formation and their reported occurrence in the Middle Silurian strata in North America.

Age	Lower Llandovery			Upper Llandovery			Llandovery Wenlock		Wenlock	
Location	1	2	3	4	5	6	7	8	9	10
Deunffia furcata									X	X
D. monospinosa								*?		
D. ramusculosa									X	X
D. ramusculosa var. *rochesterensis*										
Domasia amphora				X	?	?				
D. bispinosa				X					X	
D. canadensis										
D. canadensis var. *A.*										
D. elongata				X			X	X	X	X
D. rochesterensis										X
D. trispinosa							X		X	
Leiofusa algerensis				X						
Eupokilofusa striatifera		X	X	X			X	X	X	X
Ammonidium microcladum						X	X	X		
Baltisphaeridium pilaris				X						X
Diexallophasis denticulata	X	X	X	X			X	X	X	X
Elektroiskos pogonius		X	X	X			X	X	X	X
Helosphaerisphaeridium latispinosum									?X	X
Multiplicisphaeridium arbusculiferum			X							X
M. eoplanktonicum			X							
M. fisherii		X	X	X			X	X		X
Quadraditum fantasticum								X		
Tunisphaeridium tentaculiferum		X	X				X	X		X
Visbysphaera dilatispinosa										X
Evittia monterrosa			X				X	X		
Cymatiosphaera wenlockia			X	X			X	X		X
Dictyotidium dictyotum			X							X
Duvernaysphaera aranaides				X			X	X		

*? *D. monocantha.*

Legends for locations:

1. Power Glen Fm., S. Ontario (Cramer & Cramer 1970).
2. Maplewood Shale, New York (Cramer 1968, 1970*b*).
3. Neagha Shale, New York, S. Ontario (Cramer 1970, Loeblich 1970).
4. Ross Brook Fm., Nova Scotia (Cramer 1970*b*, Loeblich 1970).
5. Gun River Fm., Anticosti Is. (Cramer 1970).
6. Jupiter Fm., Anticosti Is. (Cramer 1970).
7. Rose Hill Fm., Pennsylvania (Cramer 1969).
8. Tuscarora Fm., Pennsylvania (Cramer 1969).
9. Rochester Fm., Maryland–W. Virginia. Reaugh (pers. comm.).
10. Ilion Shale, New York. This work.

maplewoodensis. These species were not found in the Rochester Formation with the exception of *Elektoriskos pogonius*.

Deunffia furcata, *D. ramusculosa*, *D. ramuscolusa* var. *rochesterensis* and *Domasia* spp. are present in the Rochester assemblage and their absence in the Maplewood and Neagha assemblages is the most distinguishing feature.

According to Cramer and Cramer (1970, p. 1080) these differences in the acritarch assemblage are due to the existence of two distinct acritarch biofaces. In other words, Maplewood and Neagha assemblage at one end and the Rochester assemblage at the other, contain two distinct 'biofacies', the *Neoveryhachium carminae* facies and *Deunffia furcata* and *Domasia* facies. Furthermore, Cramer and Cramer do not believe that this difference between the biofacies was caused by the difference in age. However, although in NW. Spain the *N. carminae* biofacies ranges from Llandovery to Ludlow (Cramer 1970), in eastern North America the *N. carminae* facies is restricted to the *Zygobolba excavata* ostracode Zone, of Late Llandovery age; while the *Deunffia furcata* and *Domasia* facies appear in the *Paraechmina spinosa* ostracode Zone of Basal Wenlock age.

Upper Member of Ross Brook Formation of Nova Scotia. Many Rochester Formation acritarchs occur in the Ross Brook assemblage. The stratigraphically restricted (Upper Llandovery to Wenlock) but geographically well-distributed netromorphs *Domasia amphora*, *D. bispinosa*, *D. elongata*, *Leiofusa algerensis*, *Duvernaysphaera aranaides* are common to both formations (Table 2). However, *Deunffia* spp. present in the Rochester assemblage are absent in the Ross Brook assemblage (Cramer 1970*b*, p. 747), indicating the younger age of the Rochester assemblage. Cramer (1970*b*) regards this difference as a function of palaeolatitudes.

Gun River and Jupiter Formations (Upper Llandovery), Anticosti Island, Quebec. There is little in common between the acritarchs of the Rochester Formation and the Gun River and Jupiter Formations (Table 2). However, a number of species abundant in the Gun River and Jupiter assemblages (Cramer 1970*b*, p. 749) are present in the Wenlock strata of England and Visby, Baltic (see Downie 1963, pp. 646–647).

The Ilion Shale (Wenlock), Utica, New York. The Rochester acritarchs are similar to the Ilion acritarchs (Table 2). The stratigraphically restricted taxa like *Deunffia ramusculosa*, *D. furcata*, *Domasia elongata*, *D. rochesterensis* are common to both the formations, although quantitative differences occur. For example, *Deunffia* and *Domasia* spp, are abundant in the Rochester Formation but rare in the Ilion Shale.

The Rose Hill and Tuscarora Formations (Upper Llandovery), Pennsylvania. In Pennsylvania, the Rose Hill and Tuscarora formations underlie the Rochester Formation. Many long-ranging taxa in the Rochester assemblage in southern Ontario are well represented in Rose Hill and Tuscarora assemblages in Pennsylvania (Cramer 1969, p. 486) (Table 2). However, the presence of *Domasia* and the absence of *Deunffia* spp. in the Rose Hill and Tuscarora assemblages supports the present writer's contention that *Deunffia ramusculosa* appears first in the Rochester assemblage (Lower Wenlock) in the Appalachian region.

The Rochester Formation in West Virginia. The Rochester acritarch assemblage in southern Ontario has many netromorph species in common with the Rochester assemblage in West Virginia (Reaugh, personal communication; Table 2). *Domasia elongata*, *D. bispinosa* and *D. trispinosa* are especially common in the two areas. However, only a few *Deunffia ramusculosa* occur in the Rochester assemblage in West Virginia. This is attributed to its lagoonal conditions (Reaugh, personal communication).

Intercontinental comparison

The Buildwas Beds (Basal Wenlock) in Shropshire, England. The Rochester netromorphs show their greatest similarity with the Downie's assemblage type 1, which is restricted in the Buildwas Beds (Downie 1963, pp. 646–648). *Deunffia* and *Domasia* are locally abundant in both the Rochester and the Buildwas assemblage (Table 3).

TABLE 3. Selected acritarch species in the Rochester Formation and their reported occurrence in the Middle Silurian strata (Wenlock) in Britain, Europe and North Africa.

Locality, age and total number of species / Selected acritarch taxa in the Rochester Formation	Buildwas Beds (Wenlock) England Downie (1963) (48 sp.)	Hogklint Group (Wenlock) Baltic This work (23 sp.)	Belgium (Wenlock) Martin (1969) (43 sp.)	San Pedro & Furada Fms. Lland./Gedinnian N.W.Spain Cramer 1963, 66, 70 (78 sp.)	Algeria, Sahara (Wenlock) Jardine & Yapaudijan (1968) (13 sp.)
Deunffia furcata	X				
D. ramusculosa	X				
Domasia amphora	?	X	X		
D. bispinosa	X	X	X		
D. elongata	X	X	X		
D. trispinosa	X	X	X		
Eupoikilofusa stratifera		X		X	
Ammonidium microcladum	X				
Baltisphaeridium pilaris		X		X	
Diexallophasis denticulata	X	X	X	X	X
Elektoriskos pogonius		X			
Helosphaeridium latispinosum		?			
Multiplicisphaeridium arbusculiferum	X	X			
M. eoplanktonicum	X	X			
M. fisherii		X			?
Quadraditum fantasticum			X	X	
Tunisphaeridium tentaculiferum		X	X		
Visbysphaera dilatispinosa	X		X	X	
Cymatiosphaera wenlockia	X	?	X		
Dictyotidium dictyotum		X			
Duvernaysphaera aranaides		X		X	X

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Deunffia furcata	X				
D. ramusculosa	X				
Domasia amphora	?	X	X		
D. bispinosa	X	X	X		
D. elongata	X	X	X		
D. trispinosa	X	X	X		
Eupoikilofusa stratifera		X		X	
Ammonidium microcladum	X				
Baltisphaeridium pilaris		X		X	
Diexallophasis denticulata	X	X	X	X	X
Elektoriskos pogonius		X			
Helosphaeridium latispinosum		?			
Multiplicisphaeridium arbusculiferum	X	X			
M. eoplanktonicum	X	X			
M. fisherii		X			?
Quadraditum fantasticum			X	X	
Tunisphaeridium tentaculiferum		X	X		
Visbysphaera dilatispinosa	X		X	X	
Cymatiosphaera wenlockia	X	?	X		
Dictyotidium dictyotum		X			
Duvernaysphaera aranaides		X		X	X

However, the Buildwas acanthomorphs, in particular the *Visbysphaera meson* complex (*V. oliogofurcatum*, *V. meson*, *V. brevifurcata*), were not recorded in the Rochester assemblage. These taxa plus *V. dilatispinosa* (present in both areas) are now known to range from Upper Llandovery to Upper Ludlow (Lister, 1970, pp. 98–100) and their absence or scarcity in the Rochester Assemblage may be attributed to local environmental conditions.

The Högklint Group (*Wenlock*), *Visby*, *Baltic*. The Rochester acanthomorphs show some similarity with those reported by Eisenack (1954, 1955, 1959) in the Middle Silurian of the Baltic region. Of note is the absence in the Rochester assemblage of *Visbysphaera meson* complex with the exception of single specimens of *Baltisphaeridium digitatum* and *B. corallanium*. However, Cramer (1970) reports many Middle Silurian acanthomorph species in the Rochester Formation.

Eisenack obtained acritarchs by hand-picking from aqueous slurry, thus excluding netromorphs from his assemblages. The writer studied an excellently preserved acritarch assemblage from the Högklint Group, Snäckgardsbaden, Visby, and recorded the netromorphs *Domasia amphora*, *D. bispinosa*, *D. elongata*, *D. trispinosa*, and *Eupoikilofusa stratifera*. Cramer (1970, p. 67) recorded *D. elongata* in the uppermost portion of the upper Visby Marl, in Gotland. In addition, numerous species of *Baltisphaeridium*, *Micrhystridium*, *Veryhachium*, *Lophosphaeridium*, and *Leiosphaeridia* were recorded.

The Högklint netromorph assemblage is comparable with that of the Rochester assemblage (Table 3) with the exception of the absence of *Deunffia* spp. in the Högklint assemblage. Further detailed investigation of the netromorph distribution in Högklint group is needed for a more precise correlation.

The Wenlock Assemblage from the Montagne Noire, *France*. The Rochester acritarchs have little in common with the Wenlock assemblage from France. *Micrystridium*, *Veryhachium*, and *Baltisphaeridium* species common to two areas are long ranging (Llandovery to Emsian). Of the 16 species in France (Deflandre, 1942), 10 were identified in Coalbrookdale Beds (i.e. post-Buildwas Beds) in England (Downie 1963, p. 646). All these taxa are now known to be long-ranging.

The Wenlock Assemblage from Belgium. Of the 21 species in the Rochester Formation 9 occur in the Wenlock of Belgium (Table 3). The Belgian assemblage like the Högklint assemblage shows the presence of *Domasia* and the absence of *Deunffia* (except the rare occurrence of *D. monocantha* in pre-Wenlock strata). The absence of *Deunffia* complex from the Wenlockian of Baltic and Belgium, and its abundance in the Buildwas Beds and the Rochester Formation is worthy of note. However, *Neoveryhachium carminae* present in the Belgian assemblage does not occur in either the Buildwas or the Rochester assemblage.

The San Pedro and Furada Formations in North-West Spain. A small number of Rochester taxa present in the Spanish assemblage range in age from Upper Llandovery to Gedinnian (Table 3). There seems to be a provincial differentiation between the two assemblages. The Spanish are dominated by *Neoveryhachium carminae* and numerous local species of *Veryhachium* and *Baltisphaeridium*. In contrast the Rochester is generally dominated by the *Deunffia* and *Domasia* complex, micrhystrids and leiospherids. This striking difference suggests the existence of different microplankton provinces. Cramer (1970) believes such differences to be climatically controlled.

Wenlock Assemblages from the Sahara, Algeria. Little similarity exists between the Rochester taxa and the Wenlockian taxa in the Sahara (Table 3). Long-ranging (Upper Llandovery/Ludlow) species common to both areas are *Diexallophasis denticulata*, *Multiplicisphaeridium fisherri* (*Baltisphaeridium* sp. 5 of Jardine and Yapaudjian 1968), *Evittia remota* (*Veryhachium* sp. 2 of Jardine and Yapaudjian 1968), and *Duvernaysphaera aranaides* (*Pterospermopsis* cf. *Helios* of Jardine and Yapaudjian 1968). Netromorphs (*Deunffia* and *Domasia*) are not reported from the Sahara. The closer link of Saharan and Spanish assemblages is notable, in particular the presence of *Neoveryhachium carminae.*

Palaeobiogeographic and palaeoclimatic considerations

Several palaeontologists, especially Bassler (1906, p. 8, 1911) and recently Owen (1969, p. 621), have showed interest in possible links of the Wenlockian Appalachian, Welsh Borderland, and Baltic faunas. It is therefore appropriate to discuss the relationship of the microflora in these regions.

Comparative Microflora. In order to do this, only stratigraphically restricted netromorphs are considered. The species common to more than one locality are as follows:

Species	America (Rochester Fm.)	Britain (Buildwas Beds)	Gotland (Högklint Gp.)
Deunffia furcata	Present	Present	Missing
D. monospinosa	Present	Present	Missing
D. ramusculosa	Present	Present	Missing
Domasia amphora	Present	?	Present
D. bispinosa	Present	Present	Present
D. elongata	Present	Present	Present
D. trispinosa	Present	Present	Present

This comparison suggests that the Rochester microflora had more links with the British than with the Baltic area.

Cramer (1970) suggested that acritarch 'biofaces' are due mainly to climatic factors. He proposed three biofacies: (1) *Neoveryhachium carminae*, (ii) *Domasia* and *Deunffia*, and (iii) *Baltisphaeridium corallinum.* The last biofacies partially coincides with the *Domasia* and *Deunffia* biofacies.

In North America and western Europe, Cramer (1970) found the distribution of these biofacies roughly paralleled palaeolatititudes (Cramer 1970, text-fig. 6). The *N. carminae* biofacies occurred in south-east U.S.A. and the Iberian Peninsula and, the *Domasia* and *Deunffia* biofacies in the Central Appalachian region and the Welsh Borderland.

The Rochester acritarch assemblage belongs to the *Domasia* and *Deunffia* biofaces and is similar to the Buildwas assemblage in England. However, the Baltic assemblage (Högklint Beds), although similar, shows the absence of the *Deunffia* complex. The *Deunffia* complex in the Rochester and Buildwas assemblages may represent a local climatic zone, separated by a narrower Atlantic ocean. This independently supports Owen (1969), who on the basis of bryozoa study, suggests similar climatic zones and a narrower Atlantic ocean for the similarity of Wenlockian bryozoa faunas of the

Appalachian and Welsh Borderland. A marked difference between these and the Baltic faunas is attributed to a different climate. However, these suggestions are at variance with those of other workers. Cramer (1970) considers the *Domasia* and *Deunffia* biofacies in the Rochester and Buildwas strata and the *Domasia* biofacies in Högklint strata to be indicative of a similar climate. Størmer (1967, p. 209) considered the Silurian fossiliferous reefs of Gotland to be facies of the eastern European Platform, having little connection with the Caledonian geosyncline. This would explain the similarity of the Appalachian and Welsh Borderland biota and their differences from those of Gotland. But Paul's (1967) investigations of Silurian cystids suggest that Echinoencrinitidae and Callocystitidae present in Britain originated from the Baltic and North America respectively. This would call for connections between these areas, a suggestion made earlier by Owen (1969).

REFERENCES

BASCHNAGEL, R. A. 1942. Some microfossils from the Onondaga Chert of central New York. *Bull. Buffalo Soc. Nat. Sci.* **17,** 1–8.

BASSLER, R. S. 1906. The bryozoan fauna of the Rochester Shale. *Bull. U.S. Geol. Surv.* **292,** 1–137.

BOLTON, T. E. 1957. Silurian stratigraphy and Paleontology of the Niagara escarpment in Ontario. *Mem. Geol. Survey. Can.* **289.**

BRITO, I. M. 1967. Silurian and Devonian acritarcha from the Maranhao Basin, Brazil. *Micropaleontology*, **13,** 373–482.

BRITO, I. and SANTOS, A. 1965. Contribuicáo ao conheciments dos microfósseis Silurianos e devonianos da Bacia do Maranháo. *Notas Prelim. Estudos, Divisád Geol. Mineral*, Río de Janeiro, **129,** 3–22.

CALEY, J. F. 1940. Paleozoic geology of Toronto–Hamilton area, Ontario. *Mem. Geol. Survey Can.* **224.**

CRAMER, F. H. 1964. Microplankton from three paleozoic formations in the province of Leon (N.W. Spain). *Leidse. Geol. Meded.* **30,** 253–361.

—— 1968. Palynolgic microfossils of the Middle Silurian Maplewood Shale in northwestern New York. *Rev. Micropaleont*, **11,** 61–70.

—— 1969. Possible implications for Silurian paleogeography from phytoplancton assemblages of the Rose Hill and Tuscarora Formation of Pennsylvania. *J. Paleont.* **43,** 485–491.

—— 1970. Distribution of selected Silurian acritarchs. *Rev. Espan. de micropaleont*. Spec. Pub. 202 pp.

—— 1970*b*. Acritarchs and chitinozoa from the Silurian Ross Brook Formation Nova Scotia. *Jour. Geology*, **78,** 745–749.

—— DIEZ, M. and CRAMER DEL CARMEN, R. 1968. Consideraciones taxonomicas sobre las acritaras del Silurico Medio y Superior del Norte de Espana las acritarcas acantomortificas. *Boletin. I.G.M. Espana*, **79,** 541–574.

—— —— 1970. Acritarchs from the lower Silurian Neahga Formation, Niagara Peninsula, North America. *Canadian Jour. of Earth Sc.* 1077–1085.

DEFLANDRE, G. 1942. Sur les hystrichosphères des calcaires siluriens de la Montagne Noire. *C.R. Acad. Sci. Paris*, **215,** 475–476.

—— 1945. Microfissiles des calcaires Siluriens de la Montagne Noire. *Ann. Paléont.* **31,** 41–76.

—— 1946. Hystrichosphaeridés 111. Espèces du Primaire. Fichier micropaléont., sér. 8. *Arch. Orig. Serv. Docum. C.N.R.S.*, no. 257, parts I–V, cards 1096–1185.

—— and DECLANDRE-RIGAUD, M. 1964. Fichier micropaleontologique genérale-série 12. Acritarches 1 Polygonomorphitae-Netromorphitae pro parte. *Centre National de la Recherche Scientifique generale-sèrie 13. Acritarches.*

—— and DEFLANDRE, M. 1964. Notes sur les Acritarches. *Rev. Micropal.* **7,** 111–114.

DEUNFF, J. 1954. *Veryhachium* genre nouveau d'hystrichosphères du Primaire. *C.R. Somm., Soc. Géol. Fr.* **13,** 305–306.

—— 1954*a*. Sur un microplancton du Devonien du Canada recelant des types nouveaux d'hystrichosphaerides. *C.R. Acad. Sci. Paris*, **239,** 1064–1066.